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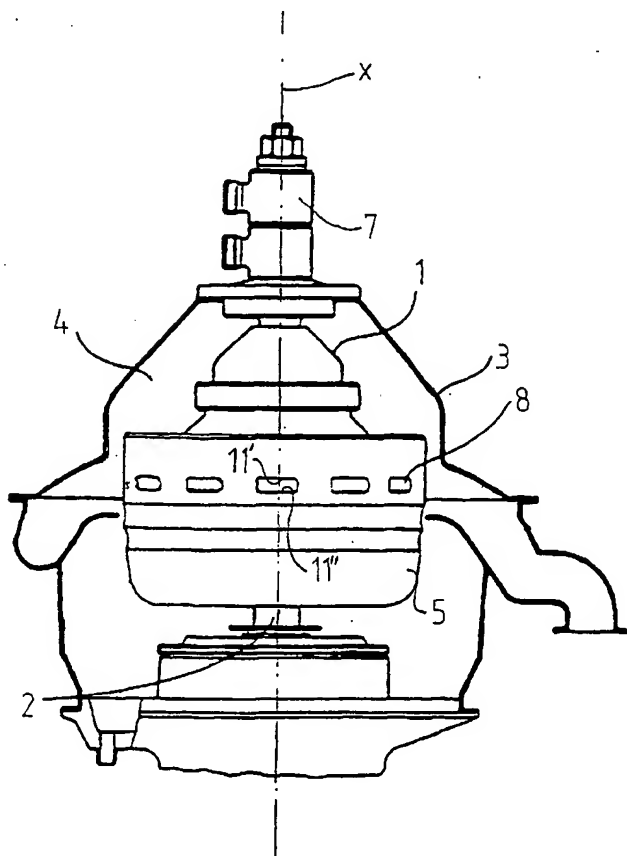
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[Continued on next page]

(54) Title: A CENTRIFUGAL SEPARATOR AND A CENTRIFUGE ROTOR



(57) Abstract: The invention refers to a centrifugal separator with a centrifuge rotor (1) and a casing (3), and such a centrifuge rotor. The rotor is rotatable in a rotary direction around a rotary axis (X). The casing (3) forms an outer space (4) for the rotor. The rotor (1) includes a rotor wall (5), which defines an outer periphery of the rotor and encloses an inner space, at least an inlet (7), which extends through the rotor wall (5) and permits feeding of a product to the inner space, and a number of outlets (8), which extend through the rotor wall and are arranged to permit intermittent discharge of a separated product from the inner space to the outer space (6). The outlets (8) are distributed around the periphery of the rotor and the number of outlets (8) is uneven.

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**A centrifugal separator and a centrifuge rotor**

THE BACKGROUND OF THE INVENTION AND PRIOR ART

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The present invention refers to a centrifugal separator according to the preamble of claim 1. The invention also refers to a centrifuge rotor according to the preamble of claim 13. The centrifugal separator includes such a rotor,  
15 which is rotatable in a rotary direction around a rotary axis, and a casing, which forms an outer space for the rotatable rotor. The rotor includes a rotor wall, which defines an outer periphery of the rotor and encloses an inner space, at least an inlet, which extends through the  
20 rotor wall and permits feeding of a product to the inner space, and a number of outlets, which extend through the rotor wall and are arranged to permit intermittent discharge of a separated product from the inner space to the outer space. Said outlets are distributed around the periphery of  
25 the rotor.

During operation of such a centrifugal separator, sounds are generated, and more precisely, the rotor may generate so called whistle, i.e. sound generated in cavities of the  
30 rotor. The sound level of such whistle may sometimes be unacceptably high and exceed the level of structural sounds from other sound sources of the centrifugal separator, for instance from turbulent pressure fluctuations in said outer space and internally in the rotor, and from the transmission  
35 and the motor.

Whistle arises in the cavities in the rotor wall, which are formed by said outlets, due to the fact that the cavities, which enclose a gas volume, have a velocity in relation to the gas, which is located outside the cavities in said outer space. Whistle is excited by this gas, normally air, when it passes the orifices of the cavities towards the outer space and causes the gas located in the cavity to vibrate. The whistle tendency increases generally with an increasing rotary speed of the rotor.

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There is a relation between the presence of whistle and the geometry of the cavities, and more precisely the frequency of such whistle is determined by the shape and dimensions of the cavities. Whistle may thus be limited by a change of this geometry. The possibilities of making such geometrical changes are limited by the strength requirements, which are set up for the material portions, which are present between adjacent cavities and which connect an upper part of the rotor to a lower part thereof.

20

SE-B-463 903 discloses such a centrifugal separator. The centrifuge rotor includes a number of outlets, which extend through the rotor wall for discharging a separated product from the inner space of the rotor to an outer space outside the rotor. The outlets are evenly distributed around the periphery of the rotor. In order to disturb the formation of sound waves in the outlets, projections in the form of elongated ribs are provided between the outlets.

SE-C- 505 385 discloses a similar centrifugal separator with a rotor having a number of outlets, which are evenly distributed around the periphery of the rotor. In this document, a geometrical change of said outlets are proposed in order to provide a reduction of the generated sound level. More precisely, outlets are disclosed, which have a decreasing cross-section area from the outer side of the

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rotor wall to a position between the outer side and the inner side.

#### SUMMARY OF THE INVENTION

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The object of the present invention is to reduce the sound level during operation of a centrifugal separator, and in particular to reduce whistle from the centrifuge rotor.

10 This object is obtained by the centrifugal separator initially defined, which is characterised in that said number of outlets is uneven.

The applicant has shown that there is an acoustic coupling  
15 in the peripheral direction of the rotor between the eigenmodes, i.e. whistle tunes, which are generated in the different outlets. By providing the rotor with an uneven number of outlets, this coupling will be disturbed. The energy in the eigenmodes, which have such a coupling to the  
20 adjacent outlets that the acoustic natural vibration has nodal points between the outlets and phase-shifted anti node in every second outlet, will be weakened and thus the sound excitation is also reduced. Suitable number of uneven outlets may be a prime number or at least 5 or at the most  
25 17 outlets, preferably at least 7 and at most 15 outlets, or more preferably at least 9 outlets and at most 13 outlets. Especially, the rotor may include 11 outlets.

According to an embodiment of the invention, the rotor  
30 includes a valve member, which is provided inside said outlets and arranged to be in a closed position, in which said discharge is prevented, and in an opened position, respectively, in which said discharge is permitted. In that connection, the valve member may, in the closed position,  
35 extend around the rotor wall in such a manner that a gap-

like space is formed between the rotor wall and the valve member at the level of said outlets.

5 According to a further embodiment of the invention, the separator is arranged to rotate the rotor at a rotary speed of at least 3000 rpm (revolutions per minute), preferably at least 4000 rpm and more preferably at least 5000 rpm.

10 According to a further embodiment of the invention, each outlet forms a cavity through the rotor wall, wherein each cavity has a main direction extending outwardly with regard to said rotary axis and rearwardly with regard to said rotary direction. Such a shape of the cavity is advantageous for an efficient, intermittent discharge of the separated  
15 product. The intermittent discharge takes place during a relatively short period of time. During the main time of the operation of the centrifugal separator when no such discharge does take place, a gas, which is relatively still standing in relation to the rotor, will be present in the  
20 cavity. Each such cavity may with regard to said rotary axis have an upper limiting wall and a lower limiting wall, which walls are substantially parallel to each other and to a radial plane. Advantageously, said outlets may be produced by milling.

25

According to a further embodiment of the invention, said outlets are evenly distributed around the periphery of the rotor. Furthermore, said outlets may be distributed around the periphery of the rotor at substantially the same axial  
30 position with regard to said rotary axis and be substantially identical.

The object is also obtained by the centrifuge rotor initially defined, which is characterised in that said  
35 number of outlets are uneven.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be described more closely by a description of various embodiments, disclosed as examples,  
5 and with reference to the drawings attached, in which

- Fig 1 discloses schematically a partly sectional side view of a part of a centrifugal separator according to the invention,  
10 Fig 2 discloses an axial section through a rotor of the centrifugal separator in Fig 1,  
Fig 3 discloses a radial section along the line III-III in Fig 2,  
Fig 4 discloses a diagram of the sound level of a  
15 centrifuge rotor with 11 outlets, and  
Fig 5 discloses a diagram of the sound level of a previously known centrifuge rotor with 12 outlets.

## DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS OF THE INVENTION

20

Fig 1 discloses a centrifugal separator including a centrifuge rotor 1, which in the following is called the rotor 1 and which is carried by a substantially vertical spindle 2. The spindle 2 with the rotor 1 is rotatable in a  
25 rotary direction d, see Fig 3, about a rotary axis x. Furthermore, the centrifugal separator includes a substantially stationary frame, which is illustrated by and includes a casing 3 forming an outer, gas-containing space 4 for the rotor 1.

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The spindle 2 is journalled in said frame by means of an upper bearing and a lower bearing, not disclosed. Furthermore, the spindle 2 is connected to a drive member, not disclosed, which is arranged to rotate the rotor 1 at a  
35 high rotary speed of between 3000 and 5000 rpm (revolutions

per minute), for instance at least 3400, at least 3800, at least 4000, at least 4400 or at least 4800 rpm.

The rotor 1 includes a rotor wall 5, which defines an outer  
5 periphery of the rotor 1 and encloses an inner space 6 in  
the rotor 1. In the inner space 6, there are components  
known per se as being indicated in Fig 2. Furthermore, the  
rotor 1 includes an inlet 7, which includes an inlet pipe  
10 extending substantially vertically through the rotor wall 5  
to a central position in the inner space 6, and which  
permits feeding of a product to the inner space 6. The rotor  
1 also has a number of outlets 8, which extend through the  
rotor wall 5 and are arranged to permit intermittent  
15 discharge of a separated product from the inner space 6 to  
the outer space 4.

The rotor 1 includes a substantially circular, bowl-shaped  
valve member 9, which is provided in the inner space 6  
inside the outlets 8. The intermittent discharge is obtained  
20 by means of the valve member 9, which is arranged to take  
one of two possible positions, i.e. a closed position, in  
which the discharge of the separated product is prevented,  
and an opened position, respectively, in which such  
discharge is permitted, normally during a very short period  
25 of time in relation to the time period during which the  
valve member 9 is closed. The valve member 9 extends in the  
closed position around the inner side of the rotor wall 5 in  
such a way that a gap-like space 10 is formed between the  
rotor wall 5 and the valve member 9 at the level of said  
30 outlets 8.

Each outlet 8 forms a cavity 11, which extends through the  
rotor wall 5. Each such cavity 11 has a main direction,  
which extends outwardly with regard to the rotary axis x and  
35 rearwardly with regard to the rotary direction d. Each such  
cavity 11 has, with regard to the rotary axis x, a first,



upper, substantially plane limiting wall 11' and a second, lower, substantially plane limiting wall 11'', which are connected to each other by curved side walls. The limiting walls 11' and 11'' are substantially parallel to each other and to a radial plane. The outlets 8 are produced by milling.

The outlets 8 are evenly distributed around the periphery of the rotor 1, i.e. the distance between adjacent outlets 8 is constant around the periphery of the rotor 1. Furthermore, the outlets 8 are distributed around the periphery of the rotor at the same level, i.e. at the same axial position with regard to the rotary axis x. All the outlets 8 are also substantially identical.

The cavities 11 of the outlets 8 will during operation, and when the valve member 9 is in the closed position, thus enclose a gas, preferably air, which is substantially still standing in relation to the rotor 1. This gas volume will be brought to vibration by the shear layer, which is formed in the outer space 4 most closely to the outer side of the rotor wall 5 and which has a high speed in relation to the gas volume in the cavities 11. Since the geometrical shape of the different cavities 11 is identical, the generated eigenmodes will be substantially equal and propagate acoustically via the adjacent spaces, in particular via the gap-like space 10 with nodal points in the different cavities 11.

As appears from Fig 3, the rotor 1 has an uneven number of outlets 8 and cavities 11. In the embodiment disclosed, the rotor 1 is provided with 11 such outlets 8. According to the invention, the rotor may also have 3, 5, 7, 9, 13, 15, 17, 19 or a larger number of uneven outlets 8. Thanks to the uneven number of outlets 8, such an acoustic propagation of the generated eigenmodes will be prevented.

The applicant has performed comparing trials at a rotary velocity of 4265 rpm with a centrifuge rotor, which includes an uneven number of outlets 8, and more precisely 11 outlets, see Fig 4, and a previously known centrifuge rotor, which includes 12 outlets, see Fig 5. As appears from Figs 4 and 5, the sound level is lower for the centrifuge rotor with 11 outlets for substantially all frequencies within the frequency range from 0 to 3 kHz.

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The invention is not limited to the embodiment disclosed but may be varied and modified within the scope of the following claims. In particular, it is to be noted that the invention is not limited to the disclosed shape of the outlets 8 but these may be shaped in a variety of different manners.

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Claims

1. A centrifugal separator including a centrifuge rotor (1), which is rotatable in a rotary direction (d) around a rotary axis (x), and a casing (3), which forms an outer space (4) for the rotatable rotor, wherein the rotor (1) includes a rotor wall (5), which defines an outer periphery of the rotor and encloses an inner space (6), at least an inlet (7), which extends through the rotor wall (5) and permits feeding of a product to the inner space (6), and a number of outlets (8), which extend through the rotor wall (5) and are arranged to permit intermittent discharge of a separated product from the inner space (6) to the outer space (4), wherein said outlets (8) are distributed around the periphery of the rotor (1), characterised in that said number of outlets (8) is uneven.

2. A centrifugal separator according to claim 1, characterised in that the rotor (1) includes a valve member (9), which is provided inside said outlets and arranged to be in a closed position, in which said discharge is prevented, and in an open position, respectively, in which said discharge is permitted.

3. A centrifugal separator according to claim 2, characterised in that the valve member (9) in the closed position extends around the rotor wall (5) in such a way that a gap-like space (10) is formed between the rotor wall (5) and the valve member (9) at the level of said outlets (8).

4. A centrifugal separator according to any one of the preceding claims, characterised in that the centrifugal separator is arranged to rotate the rotor (1) at a rotary speed of at least 3000 rpm.

5. A centrifugal separator according to any one of the preceding claims, characterised in that the centrifugal separator is arranged to rotate the rotor (1) at a rotary speed of at least 4000 rpm.

5

6. A centrifugal separator according to any one of the preceding claims, characterised in that the centrifugal separator is arranged to rotate the rotor (1) at a rotary speed of at least 5000 rpm.

10

7. A centrifugal separator according to any one of the preceding claims, characterised in that each outlet (8) forms a cavity through the rotor wall (5), wherein each cavity (11) has a main direction extending outwardly with regard to said rotary axis (x) and rearwardly with regard to said rotary direction (d).

15

8. A centrifugal separator according to claim 7, characterised in that each such cavity (11) with regard to said rotary axis (x) has a first limiting wall (11') and a second limiting wall (11''), which walls are substantially parallel to each other and to a radial plane.

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9. A centrifugal separator according to claim 8, characterised in that said outlets (8) are produced by milling.

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10. A centrifugal separator according to any one of the preceding claims, characterised in that said outlets (8) are evenly distributed around the periphery of the rotor (1).

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11. A centrifugal separator according to any of the preceding claims, characterised in that said outlets (8) are distributed around the periphery of the rotor (1) at substantially the same axial position with regard to said rotary axis (x).

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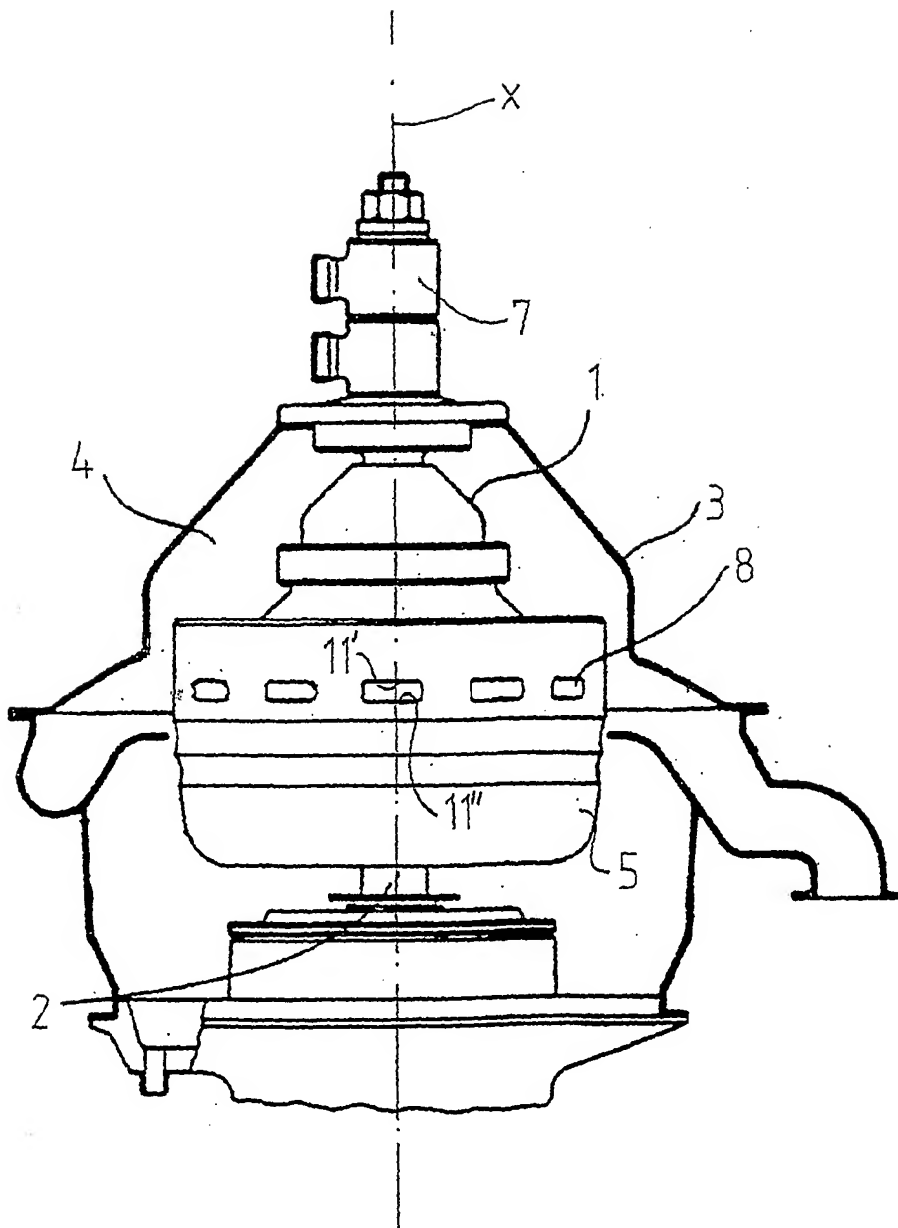
12. A centrifugal separator according to any one of the preceding claims, characterised in that said outlets (8) are substantially identical.

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13. A centrifuge rotor for a centrifugal separator, wherein the rotor (1) is arranged to be rotatable in a rotary direction (d) around a rotary axis (x), wherein the rotor (1) includes a rotor wall (5), which defines an outer  
10 periphery of the rotor (1) and encloses an inner space (6), at least an inlet (7), which extends through the rotor wall (5) and permits feeding of a product to the inner space (6), and a number of outlets (8), which extend through the rotor wall (5) and are arranged to permit intermittent discharge  
15 of a separated product from the inner space (6) to an outer space (4) outside the rotor (1), wherein said outlets (8) are distributed around the periphery of the rotor (1), characterised in that said number of outlets (8) is uneven.

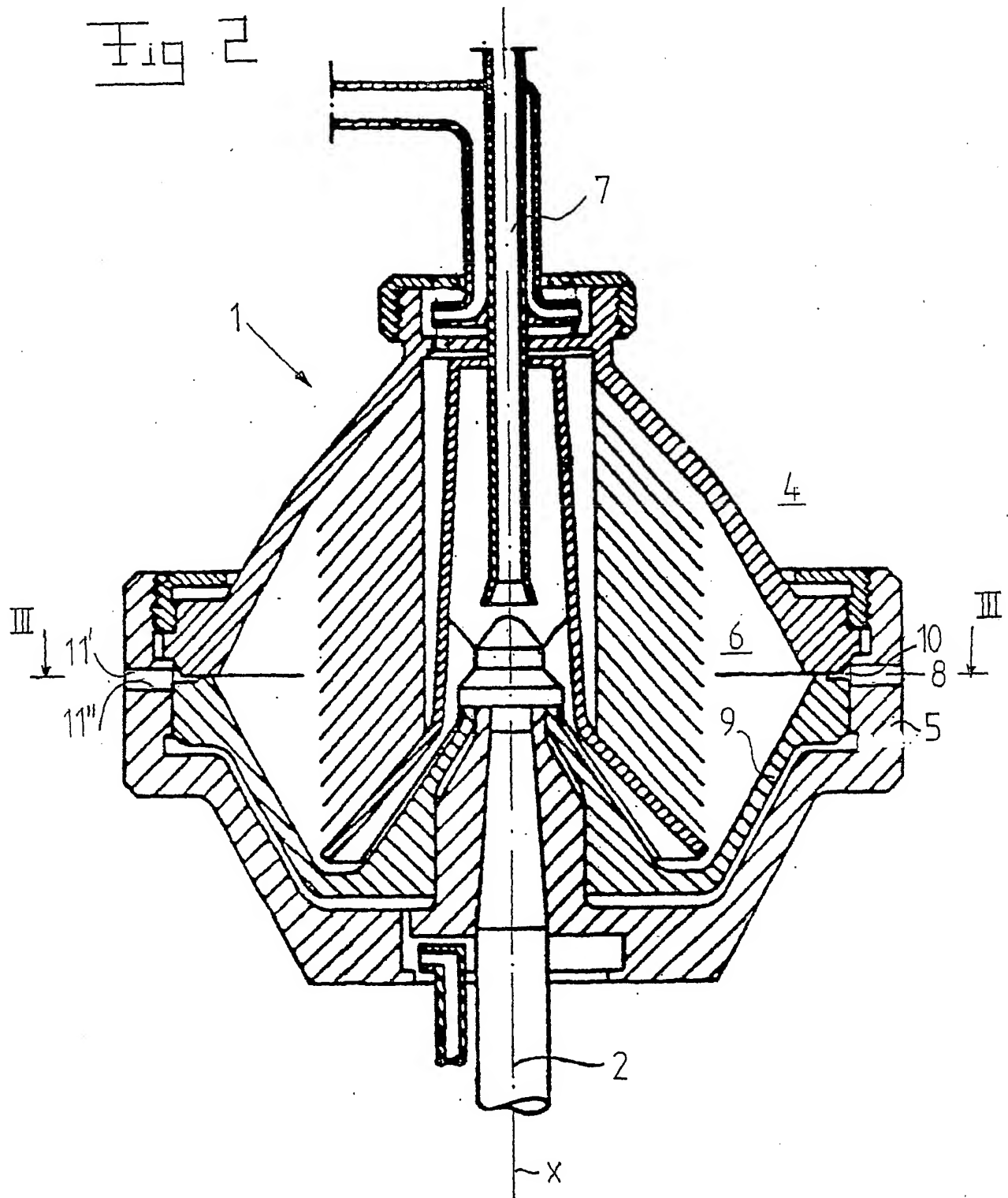
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Fig 1

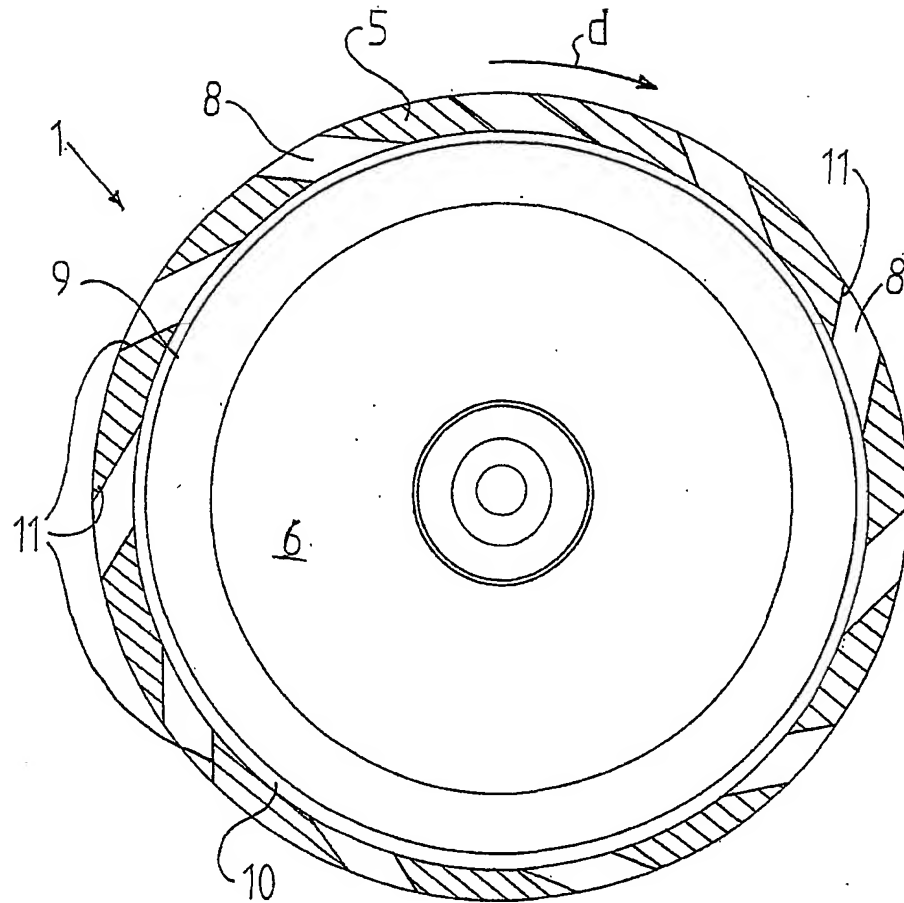
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Fig 2



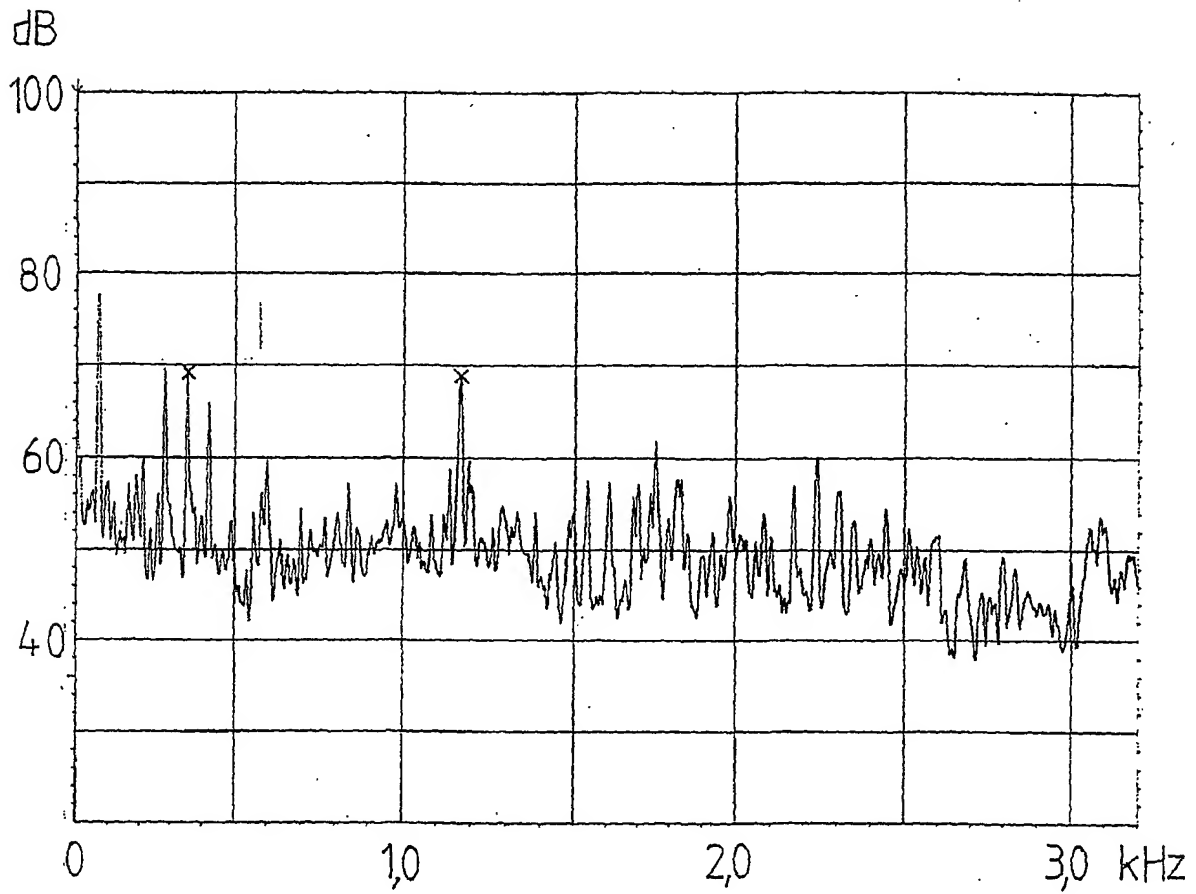
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Fig 3

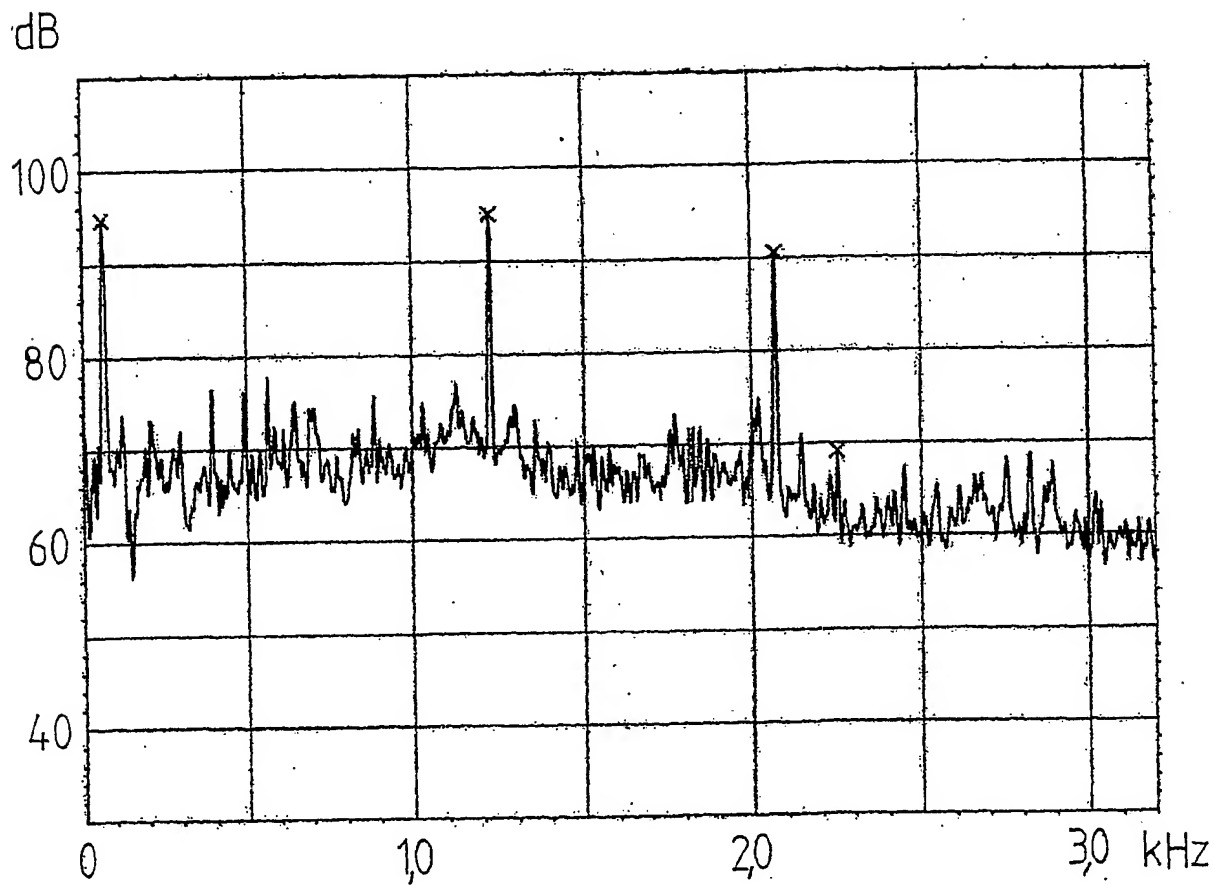




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Fig 4

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Fig 5

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 01/02538

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B04B 7/08

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI,PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SE 463903 B (ALFA-LAVAL SEPARATION AB), 11 February 1991 (11.02.91), claim 1, abstract  --	1-13
A	SE 505385 C2 (ALFA LAVAL AB), 18 August 1997 (18.08.97), page 2, line 6 - line 20, abstract  -- -----	1-13

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

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"&amp;" document member of the same patent family

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## INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.

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